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Output adjusting cartels facing dynamic, convex demand under uncertainty: The case of OPEC

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ABSTRACT

This paper analyzes the optimal strategy of a monopoly facing stochastic and dynamic demand and choosing a Cournot-type strategy, more precisely, adjusting its output. This investigation is motivated by the decisions of OPEC to adjust its output and by the again high and volatile oil prices. The oil market characteristics – uncertainty, dynamic and convex demand, and a quantity adjusting cartel – provide in turn an explanation for two different kinds of volatility for oil prices, small and large. Moreover, it makes a difference in such a setting whether OPEC plays in prices (as it did up to 1985) or in quantities (its current policy) and the model implications are compatible with the observed pattern. The numerical example, even accounting for all necessary caveats, suggests that OPEC may not be a perfect cartel but even assuming that OPEC behaves like a duopoly would lead to much larger supplies.

1. Introduction

This paper studies optimal noncompetitive quantity strategies when the evolution of demand is sluggish and convex and demand and supply are stochastic processes. One objective is to solve the corresponding dynamic stochastic optimization problem. The other objective is to improve our understanding of oil prices, because this investigation is motivated by the Organization of Petroleum Exporting Countries (OPEC), which faces a market with the above characteristics and which pursues a quantity adjustment policy. Of course, the economic importance of oil, the dramatic evolution of oil prices during 2005–2008 (see BP (2011)), and today's high oil prices provide further reasons. In order to appreciate the surprise and shock caused by the high oil prices during 2008 and by today's levels of above $100/b, it is worth recalling past expert assessments, e.g.: US Department of Energy (2001) and International Energy Agency (2004) were both promising a doubling of Middle East output at $25 per barrel, and Salameh (2004) predicted that prices are unlikely to rise above $50 per barrel; Fischer et al. (2009) reveal continuous underestimations of demand in the EIA's (short term) forecasts.

Some characteristics are crucial when modeling cartels in general and OPEC decisions in particular. The first crucial but by and large ignored aspect is that OPEC has stopped posting official crude oil prices at the end of 1985. OPEC's abandonment of its price strategy and the associated increase of Saudi Arabia's oil production led in 1986 to a dramatic decline in oil prices from above $30/b to below $10/b. OPEC is since then a quantity adjusting cartel that determines at least twice a year at the 'Conference' how to adjust its output. Indeed, many cartels find it easier to agree on changes in production than to fix prices if only to avoid anti-trust law enforcement. Furthermore, reducing output, probably citing technical reasons (a strategy for which electric utilities are sometimes blamed) looks much more innocent than raising prices. This allowed OPEC ministers to blame speculators for the high oil prices; Brunetti et al. (2013) cite that Hugo Chavez and the Saudi oil minister Mr. Ali al-Naimi claimed that oil prices had been forced up by speculation rather than underlying supply and demand pressures. Therefore, all what follows and which is attributed to OPEC, allows for a broader range of applications. The second crucial point is the substantial difference between short and long run price elasticities, i.e., the demand for OPEC oil is dynamic and characterized by large time constants. A third characteristic is uncertainty in energy markets. Part of this uncertainty, but not all as will be shown in this paper, is reflected in volatile prices not only for oil but also for gas and electricity. In fact, Regnier (2007) finds that oil prices are more volatile even if compared with the narrower class of commodities after decades of stability (before 1973), which suggests reasons in addition to economic up and down turns. Conversely, Nakov and Pescatori (2010) show how the low and stable oil prices from 1986 to 2004 contributed to US macro-economic stability.

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Sluggishness of energy and oil demand renders repeated game versions of static oligopoly games (supergames', e.g., along the lines of Green and Porter (1984); Brock and Scheinkman (1985); Rotemberg and Saloner (1986)) inappropriate. Keane (2010) stresses that the assumption of static demand, although very common in IO, is inappropriate, 'not small potatoes', in many applications. Nevertheless, many papers ignore the importance of sluggishness in the energy markets and use static demand relations in order to test empirically the cartel hypothesis for OPEC behavior. The paper of Griffin (1985) has been followed up by several authors, e.g., Griffin and Xiong (1997), including extensions into different directions, e.g., in Mason and Polasky (2005) for political variables (of low power). Smith (2005) criticizes these approaches, obtains himself mixed results (OPEC is more than a non-cooperative oligopoly but less than a frictionless cartel, which is in line with the assumption in Rauscher (1992)), and stresses the uncertainties and difficulties faced by such an analysis.

OPEC decisions are crucial for the international oil and energy markets, because the prices of all other fuels are linked to the oil price, either directly (e.g. natural gas contracts in Europe), or indirectly (via supply/demand interactions). Given the economic importance it is surprising that only few papers attempt to explain these ups and downs of oil prices. In fact, many papers argue to the contrary that OPEC pursues a target similar to central banks trying to stay within exchange rate bands, e.g., Tang and Hammoudeh (2002) for price, Powell (1990) and Suranovic (1993) for capacity utilization. Oil price volatility or cycles are model outcomes in Wirl (1990), Cremer and Isfahani (1991) and in Rauscher (1992) where OPEC behavior is modeled by a perfect cartel with perfect competition. Wirl and Caban (2012) apply a dynamic and convex demand framework similar to the one in this paper but focuses on the price strategy, which is different from strategy analyzed in this paper (this difference is briefly addressed in Section 5). Cremer and Isfahani (1991) refer to multiple equilibria due to backward bending supply curves that are also crucial role in the dynamic model of Rauscher (1992).

Most of the recent papers on oil prices apply similar econometric methods to high frequency data (monthly or daily). One focus of these many papers is to what extent speculation caused the 2008 oil price surge, e.g., Hamilton (2009), Kilian (2009, 2010), Kesicki (2010), Kaufmann (2011), Büyüksahin and Harris (2011), Lammerding et al. (2013) and Hache and Lantz (2013) The result of this literature (not restricted to this sample) is mixed. Quite a number of papers focus on related specifics: Mu and Ye (2011) focus and reject the China factor' as explanation of this price surge, Salisu and Fasanya (2013) find and link the structural breaks to the Iraq/Kuwait conflict (1990) and the financial crisis in 2008, and Wang et al. (2011) test whether GARCH-type models (widely used in this literature) can well capture the long memory in the volatility of oil price (WTI) returns; others investigate oil price link to exchange rates, gold prices, etc.

The theoretical objective of the following paper is to study a profit maximizing cartel that chooses output adjustments as its strategy faces uncertainty and sluggish demand. Therefore, the approach of this paper is completely different and thus complementary to the recently dominating empirical investigations of oil prices. Only few papers address these or at least a subset of these characteristics. Keller and Rady (1999) consider output experimentation by a monopolist facing uncertain but static demand. Hyndman (2008) focuses on quantity setting cartels and the application to OPEC finds that bargaining is more likely to succeed in 'good times'. Wirl (2010) considers the differential game of oligopolists with dynamic but deterministic and linear demand.

Given OPEC's position and its current quantity policy, the application of these theoretical results to OPEC is too tempting. Of course, the example below is very simple but it highlights the underlying economic incentives and provides at least partial explanations of the observed oil price pattern. A major reason for this word of caution is that describing OPEC behavior faces huge uncertainties (Smith (2005)), which cannot be reflected in a small model even if it accounts explicitly for uncertainties. Nevertheless, an interesting finding of this numerical example is that the narrow view of OPEC as a business organization has some explanatory power if applied to its past behavior and the implied more recent oil price evolution.

The paper is organized as follows. Section 2 introduces the model. Section 3 derives the profit maximizing strategy for an output adjusting cartel. Section 4 applies the theoretical results to an example using parameters that are calibrated in a way to represent OPEC exports. Section 5 extends the analysis and compares the outcome with an oligopolistic framework and with OPEC choosing the price strategy. Final remarks complete this investigation.

2. Model

Based on the outline and the reasons given in the Introduction, the model rests on the following four premises:

(1) Dynamic, more precisely, sluggish demand since observed consumption is incompatible with a static demand relation and observations are realizations from a path converging (ceteris paribus) to an equilibrium relation. The concept of dynamic consumption behavior dates back at least to Friedman (1956). Sluggishness is an important characteristic of world energy markets. Demand depends on the energy efficiencies of durables with an average life time for example of above ten years for cars, and of a few decades for buildings. Significant time constants of adjustment characterize also energy supply, e.g., the time it takes to get a nuclear power plant operating, or to find and develop a new oil field. Both items add to the sluggishness that OPEC faces.
(2) Demand is getting less price sensitive at lower outputs/higher prices, i.e., a convex demand relation; Fig. 1 shows the particular convex (here logarithmic/exponential) relation used in the numerical example. A plausible explanation of the convex shape is that the more price sensitive segments of demand are reduced disproportionately as prices increase thereby increasing the share of less flexible demand segments. This is exactly what happened in the energy and oil markets. According to Dargay and Gately (2010), the past high oil prices eliminated oil more or less from power generation and reduced its share in heating and industrial uses substantially leaving by now transport as the major demand for refined products which has obviously much less flexibility due to the lack of alternative fuels (at the necessary scale).[1]
(3) Uncertainty is a crucial element in many markets. Indeed, demand shocks are offered as an explanation of the oil price evolution during 2008, first the increasing energy hunger of new consumers like China and India and then the depression following financial crisis after the Lehman bankruptcy. In the past, oil prices were often linked to supply shocks. For example, it is 'common knowledge', see the oil price chart in BP (2011), to link oil price shocks to supply shocks (and politics) such as in 1973 (the embargo around the Yom-Kippur war), during 1979–81 (due to the Iranian revolution), the spikes around the Kuwait crisis (1990/91), and the invasion of Iraq (2003). More recent examples are Hurricanes Rita and Katrina and the Arab Spring involving OPEC member Libya. The following model accounts for demand and supply uncertainty.
(4) A quantity adjusting cartel facing the above characteristics 1–3.

[1] Note that this description does not refer to shifts of the demand curve but to movements along the equilibrium curve, i.e., after all adjustments are made. If prices are kept high for a long time, the scenario described in Dargay and Gately (2010) will ultimately lower demand at which level a further reduction is much harder.